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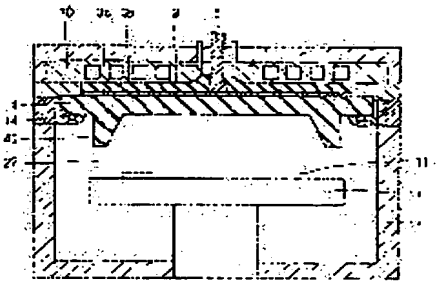
(54) PLASMA TREATMENT DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a plasma treatment device capable of generating stable plasma ranging from high pressure to low pressure by forming an optimum resonance area on a top plate in compliance with plasma conditions.
SOLUTION: It is possible to resonate at some area at any plasma condition by arranging an antenna 3 arranged at an opening at an upper part of a chamber 1, driven by a microwave to generate a electromagnetic field, and arranging the top plate 4 blocking the opening of the chamber 1 under the antenna 3, and forming a ring-shaped protruded part 41 at the lower face side of the top plate 4 with its thickness in a radial direction continuously changing in a tapered state. By this, an effect equivalent to the preparation of top plates with various thicknesses can be obtained by preparing only one kind of the top plate, the absorption efficiency of plasma can be sharply improved, and the generation of stable plasma ranging from high pressure to low pressure becomes possible.



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* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1]
The plasma generating room which contains a processed substrate and generates the plasma,
The antenna which is arranged at opening of the upper part of said plasma generating room, drives by microwave, and generates electromagnetic field,
The top plate which is formed in the lower part of said antenna, has uniform predetermined thickness in the direction of a field, and closes opening of said plasma generating room,
Plasma treatment equipment equipped with taper-like the heights or the crevice formed in the underside side of said top plate.
[Claim 2]
Said top plate contains a thick thin part and a thick part by said heights or crevice,
The thickness of said thick thin part is plasma treatment equipment according to claim 1 chosen as ** lambda/8 lambda/4.
[Claim 3]
Said heights or crevice is plasma treatment equipment containing the protruding line formed in the underside of said top plate in the shape of a ring according to claim 1 or 2.
[Claim 4]
Said top plate is disc-like,
Said protruding line is plasma treatment equipment according to claim 3 by which two or more formation is carried out in the direction of a path in the said alignment with the core of said top plate.
[Claim 5]
Said protruding line is plasma treatment equipment according to claim 3 or 4 with which the direction thickness of a path by the side of said top plate is formed more thickly than the direction thickness of a path by the side of a head.
[Claim 6]
Said heights or crevice is plasma treatment equipment given in either including the projection of the shape of **** formed in the underside of said top plate of claims 1-3.
[Claim 7]
Said conic projection is plasma treatment equipment according to claim 6 formed in the main underside of said top plate.
[Claim 8]
It is plasma treatment equipment according to claim 6 with which two or more said conic projections are prepared, and said two or more conic projections are arranged in the shape of a ring.
[Claim 9]
Said heights or crevice is plasma treatment equipment containing the 1st downward protruding line formed between the crevice of two or more shape of said ring, and said two or more ring-like crevices, and the 2nd downward protruding line formed in the outside of the ring-like crevice of the outermost periphery according to claim 8.
[Claim 10]

The thickness of said 2nd heights is plasma treatment equipment according to claim 9 thickly formed compared with the thickness of said 1st heights.

[Claim 11]

Plasma treatment equipment given in either of claims 1-10 by which the crevice is formed in the core by the side of the antenna of said top plate, and different matter from the dielectric constant of said top plate is arranged in said crevice.

[Claim 12]

The depth of the crevice of said top plate is plasma treatment equipment according to claim 11 formed in the lambda/8 or more depth.

[Claim 13]

The depth of the crevice of said top plate is plasma treatment equipment according to claim 11 formed in the lambda/4 or more depth.

[Claim 14]

The thickness of a top plate [in / said heights are formed in the core by the side of said processed substrate of said top plate, and / the circumference of said heights] is plasma treatment equipment given in either of claims 1-13 which is ** lambda/8 lambda/4.

[Claim 15]

Said processed substrate is disc-like,

Said heights or crevice is plasma treatment equipment given in either of claims 1-14 which is formed outside [at least one] the radius R from the core of said top plate when the radius of said processed substrate is set to R.

[Claim 16]

Said heights or crevice is plasma treatment equipment given in either of claims 1-15 which is formed inside [at least one] the radius D from the core of said top plate when distance of said top plate and said processed substrate is set to D.

[Claim 17]

Said antenna contains the slot plate with which the slot was formed by being distributed on the field,

Plasma treatment equipment given in either of claims 1-3 by which said heights or crevice is formed in said top plate corresponding to the location of the slot on said slot plate.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
Especially this invention relates to the plasma treatment equipment which generates the plasma in a chamber by emitting the microwave supplied to the antenna about plasma treatment equipment through the top plate which consists of a dielectric which closes opening in a chamber.
[Background of the Invention]
[0002]
In recent years, with the densification of a semiconductor device, and detailed-izing, in the production process of a semiconductor device, in order to process membrane formation, etching, ashing, etc., plasma treatment equipment is used. With the microwave plasma treatment equipment made to generate the plasma especially using microwave, he can feel easy also under the about 0.1-10Pa conditions that a pressure is comparatively low (high vacuum), and can generate the plasma. Therefore, the microwave plasma treatment equipment using microwave with a frequency of 2.45GHz attracts attention, for example.
[0003]
Drawing 11 is the sectional view showing an example of such conventional plasma treatment equipment. Plasma treatment equipment is equipped with the chamber 1 for holding a substrate 11 and performing predetermined processing to a substrate 11, RF generator 5 for generating microwave, and the antenna section 3 for emitting microwave in a chamber 1 in drawing 11 .
[0004]
The antenna section 3 has slot plate 3c, slow wave plate 3b, and antenna covering 3a, and is constituted. Two or more slots (opening) for turning and emitting microwave in a chamber 1 are formed in slot plate 3c. The microwave generated by RF generator 5 is sent to the antenna section 3 by the waveguide 6. The top plate 4 which constitutes some septa of a chamber 1 is arranged in the upper part of a chamber 1, and the seal members 14, such as an O ring, are formed between the top plate 4 and the septum of a chamber 1. The antenna section 3 is arranged above this top plate 4.
[0005]
In the chamber 1, the susceptor 7 for holding the contained substrate 11 is formed. Furthermore, the vacuum pump 9 for exhausting the inside of a chamber 1 is connected to the chamber 1. The inside of a chamber 1 is exhausted by this vacuum pump 9, and for example, argon gas is introduced in a chamber 1 as gas for generating the plasma under a predetermined pressure range.
[0006]
With above-mentioned plasma equipment, the microwave generated by RF generator 5 reaches propagation and the antenna section 3 in a waveguide 6. The microwave which reached the antenna section 3 spreads slow wave plate 3b, and is radiated on a top plate 4 through slot plate 3c. In a top plate 4, microwave produces an oscillation in the direction of a field, is spread towards a periphery from a core, and generates electromagnetic field in a chamber 1. Of the

electromagnetic field generated in the chamber 1, argon gas dissociates, the plasma production field 22 is formed between a substrate 11 and a top plate 4, and predetermined plasma treatment is performed to a substrate 11.

[0007]

In such plasma treatment equipment, it is necessary to irradiate [a substrate 11] the plasma at homogeneity. However, by the core and periphery of a top plate 4, since plasma reinforcement differs, by forming a top plate 4 in a concave surface configuration, and making distance with the periphery of a substrate 11 and a top plate 4 approach in JP,2002-299240,A, lowering of the plasma consistency in the periphery of a substrate 11 is compensated, the plasma is maintained also in low voltage processing, and making stable plasma treatment possible is indicated.

[0008]

Moreover, forming a ring-like sleeve in JP,2003-59919,A so that a plasma excitation field may not contact a dielectric window with the surface of metal of a direct-processing vessel wall, and obtaining a uniform plasma consistency on a substrate front face is indicated.

[Patent reference 1] JP,2002-299240,A

[Patent reference 2] JP,2003-59919,A

[Description of the Invention]

[Problem(s) to be Solved by the Invention]

[0009]

Plasma equipment requires a certain amount of [in the direction of a field] thickness as a top plate 4, in order to oppose the force which secures reinforcement in the chamber 1 by which the interior is decompressed, and the open air pushes. A resonance field is formed in a dielectric of microwave, strong electric field occur, a standing wave is formed [a top plate 4 is constituted by the dielectric,], electromagnetic field are produced in a chamber 1 by this standing wave, and a plasma consistency becomes high. There is thickness of the dielectric suitable for making a standing wave.

[0010]

Drawing 12 is drawing showing the field strength distribution depending on the thickness of a top plate. Drawing 12 (a) is a part to which the part which shows field strength distribution in case the thickness of the direction of a field of a top plate 4 is 22.8mm, and is shown with a main slash is strong [field strength]. Drawing 12 (b) shows the field strength distribution when setting thickness of a top plate 4 to 27.8mm, and field strength distribution is spreading on the outskirts from a core compared with drawing 12 (a). Drawing 12 (c) shows the field strength distribution when setting thickness of a top plate 4 to 31.6mm, and field strength distribution is distributed to the circumference except for a part for the core of a top plate 4, and has thickness for which were most suitable. Drawing 12 (d) shows the field strength distribution when setting thickness of a top plate 4 to 32.8mm, and, only as for the core, field strength distribution is strong. Drawing 12 (e) shows the field strength distribution when setting thickness of a top plate 4 to 37.8mm, and the field strength of a core is strong.

[0011]

In the plasma treatment equipment shown in drawing 11 , since the electron density near the plasma front face will change if plasma conditions, such as a pressure in a chamber 1 and power of microwave, are made to change, the trespass depth by which the plasma invades into the matter changes. Since a diffusion coefficient will increase if a pressure is reduced, the electron density near a plasma front face falls, and trespass depth increases. Thus, since the suitable thickness of a dielectric will change if plasma conditions are changed, the resonance field for forming a standing wave will shift. For this reason, in order to generate the plasma in the always optimal condition, there was a problem that it was necessary to prepare the dielectric which has the various thickness according to plasma conditions. Moreover, the absorption efficiency of microwave to the plasma in the low voltage force is bad, and the generation by which the plasma in low voltage (20mTorr) was stabilized becomes difficult.

[0012]

So, the object of this invention is offering the plasma treatment equipment which can generate the plasma which formed the resonance field optimal in a top plate according to plasma

conditions, and was stabilized in the chamber covering the low pressure from the high pressure.
[Means for Solving the Problem]
[0013]
This invention is characterized by to have the antenna which contains a processed substrate, is arranged at opening of the upper part of the plasma generating room which generates the plasma, and a plasma generating room, drives by microwave, and generates electromagnetic field, the top plate which is formed in the lower part of an antenna, have uniform predetermined thickness in the direction of a field, and close opening of a plasma generating room, and taper-like the heights or the crevice formed in the underside side of a top plate.
[0014]
In this invention, by the taper-like part of the heights formed in the top plate, or a crevice, change the thickness of the direction of a path continuously, it is made to resonate by somewhere in every condition of the plasma, and the optimal resonance field can be formed. Therefore, the effectiveness same with having prepared the top plate of various thickness can be done so only by preparing one kind of top plate. Thereby, the absorption efficiency to the plasma can be raised by leaps and bounds, and generating of the plasma stabilized covering the low pressure from the high pressure is attained.
[Best Mode of Carrying Out the Invention]
[0015]
Preferably, the thickness of a thick thin part is chosen as lambda/4**lambda/8 for the top plate by heights or the crevice including the thick thin part and the thick part.
[0016]
Preferably, heights or a crevice contains the protruding line formed in the underside of a top plate in the shape of a ring.
[0017]
Preferably, a top plate is disc-like and two or more formation of the protruding line is carried out in the direction of a path in the said alignment with the core of a top plate.
[0018]
Preferably, the direction thickness of a path by the side of a top plate is thicker than the direction thickness of a path by the side of a head, and a protruding line is formed.
[0019]
Preferably, heights or a crevice includes the projection of the shape of **** formed in the underside of a top plate.
[0020]
Preferably, a conic projection is formed in the main underside of a top plate.
[0021]
Preferably, two or more conic projections are prepared and two or more conic projections are arranged in the shape of a ring.
[0022]
Preferably, heights or a crevice contains the 1st downward protruding line formed between the crevice of the shape of two or more ring, and two or more ring-like crevices, and the 2nd downward protruding line formed in the outside of the ring-like crevice of the outermost periphery.
[0023]
Preferably, the thickness of the 2nd heights is thickly formed compared with the thickness of the 1st heights.
[0024]
Preferably, the crevice is formed in the core by the side of the antenna of a top plate, and different matter from the dielectric constant of a top plate is arranged in a crevice.
[0025]
Preferably, the depth of the crevice of a top plate is formed in the lambda/8 or more depth.
[0026]
Preferably, the depth of the crevice of a top plate is formed in the lambda/4 or more depth.
[0027]

Preferably, heights are formed in the core by the side of the processed substrate of a top plate, and the thickness of the top plate in the circumference of heights is ** lambda/8 lambda/4.
[0028]
Preferably, a processed substrate is disc-like, and heights or a crevice is formed outside [at least one] the radius R from the core of a top plate, when the radius of a processed substrate is set to R.
[0029]
Preferably, heights or a crevice is formed inside [at least one] the radius D from the core of a top plate, when distance of a top plate and a processing substrate is set to D.
[0030]
Preferably, corresponding to the location of the slot on a slot plate, heights or a crevice is formed in a top plate including the slot plate with which the antenna was formed by distributing a slot on a field.
[Example]
[0031]
Drawing 1 is the sectional view of the plasma treatment equipment in 1 operation gestalt of this invention, and drawing 2 is drawing which looked at the dielectric plate shown in drawing 1 from the underside.
[0032]
Plasma treatment equipment is equipped with the chamber 1 for holding a substrate 11 and performing predetermined processing to a substrate 11 like above-mentioned drawing 11 , and the antenna section 3 for emitting microwave in a chamber 1.
[0033]
The microwave generated by the RF generator which is not illustrated is sent to the antenna section 3 by the waveguide 6. The top plate 4 which closes opening of a chamber 1 and constitutes some septa of a chamber 1 is arranged in the upper part of a chamber 1, and the seal members 14, such as an O ring, are formed between the top plate 4 and the septum of a chamber 1. The antenna section 3 is arranged above this top plate 4. The cooling plate 10 with which a refrigerant flows is formed in the interior in the upper part of the antenna section 3.
[0034]
In the chamber 1, the susceptor 7 for holding the contained substrate 11 is formed. The susceptor 7 has the heater ability for heating a substrate 11. Furthermore, in order to exhaust the inside of a chamber 1, the vacuum pump shown in drawing 11 is connected to the chamber 1. The inside of a chamber 1 is exhausted by this vacuum pump, and for example, argon gas is introduced in a chamber 1 as gas for generating the plasma under a predetermined pressure range.
[0035]
With above-mentioned plasma equipment, the microwave generated by the RF generator reaches propagation and the antenna section 3 in a waveguide 6. The microwave which reached the antenna section 3 spreads slow wave plate 3b, forms a resonance field in a top plate 4 through slot plate 3c, generates a standing wave, and generates electromagnetic field in a chamber 1. Of the electromagnetic field generated in the chamber 1, argon gas dissociates, the plasma production field 22 is formed between a substrate 11 and a top plate 4, and predetermined plasma treatment is performed to a substrate 11.
[0036]
The top plate 4 is formed in the direction of a field disc-like [which has uniform predetermined thickness], in order to oppose the force which secures reinforcement and the open air pushes, and heights or a crevice is formed in the underside. Predetermined spacing is separated from the periphery of a top plate 4 in the direction of a path as heights or a crevice, and, more specifically, the ring-like protruding line 41 is formed in the periphery in the said alignment with the core of a top plate 4. A peripheral face is vertical to the underside of a top plate 4, and inner skin is formed in the shape of a taper so that it may have a predetermined include angle to a top plate 4, and as for this protruding line 41, the cross section forms rectangular heights or a rectangular crevice. Microwave is supplied to the top plate 4 from the antenna section 3, and it

has become a non-dense to the plasma consistency of a core being dense to form a protruding line 41 in the periphery of a top plate 4 by the periphery, and it is for raising the plasma consistency of a periphery.

[0037]

Drawing 3 is drawing for explaining the condition that microwave spreads the inside of a top plate. Although the thick thick part and the other thick thin part are contained by the protruding line 41, microwave stops being able to spread a top plate 4 easily due to the thick thin part of a top plate 4 by choosing the thickness of a thick thin part as lambda/4**lambda/8.

[0038]

If the reason is explained, Mode A and Mode B exist in the gestalt of the electromagnetic wave which passes through the inside of a top plate. Since Mode A exists if electron density becomes beyond a predetermined value, and Mode B exists only when electron density is comparatively small, when electron density is high to some extent, the microwave propagation by Mode B is controlled.

[0039]

However, this is greatly dependent on top-plate thickness, and by lambda/4 or more thickness, the minimum of the electron density which can control propagation with Mode B will become high, so that it becomes thick. If it becomes lambda/2 or more, since Mode B can be existed without being dependent on electron density, it becomes impossible to control propagation with Mode B. On the contrary, the minimum of the electron density which can control propagation with Mode B does not change or less by lambda/4. Therefore, if the reinforcement of a top plate is taken into consideration, lambda/4 will become the optimal. However, if it is the range of ** lambda/8, propagation with Mode B can be controlled almost.

[0040]

Although the microwave supplied to the antenna section 3 is emitted to down from the slot of the antenna section 3, as shown in drawing 3 , it is reflected within a top plate 4, and it vibrates in the direction of a field by the repeat of the echo in a top plate 4, and it forms a resonance field, and turns into a standing wave. (Though it is explanation of being hard to spread in a thick thin part, it is illustrated so that microwave may spread in the direction of a path in drawing 3 , and it is thought that it is inconsistent.) Please give supplementary information. Since it is hard coming to come out the microwave included in the protruding line section 41 to the plasma production field 22, microwave becomes is easy to be accumulated in the protruding line part 41. Thereby, the plasma consistency of the periphery by having formed the protruding line 41 can be raised. Protruding line 41 part constitutes a resonance field from a periphery of a top plate 4, and vibrates in the direction of a path in which microwave intersects perpendicularly in the direction of a field of a top plate 4.

[0041]

Since the protruding line 41 is formed in the shape of a taper to the thing with the thick direction thickness of a path by the side of a top plate 4 so that the direction thickness of a path by the side of a head may become thin, the part whose thickness of the amplitude and protruding line 41 which vibrate in the direction of a path corresponds surely exists. That is, since a protruding line 41 constitutes a resonance field in the periphery of a top plate 4 and a resonance field goes up and down it automatically according to a plasma consistency, the place which resonates by somewhere in every condition of the plasma exists.

[0042]

Since the optimal resonance field for a top plate 4 can be formed by this, strong electric field are generated, a standing wave can be formed, a plasma consistency can be made high, and generating of the plasma stabilized covering the low pressure from the high pressure is attained.

[0043]

In addition, this protruding line 41 may form a peripheral face and inner skin side in the shape of a taper. Moreover, what is necessary is just to choose as arbitration the location or configuration which arranges a protruding line 41 according to the thickness of a top plate 4.

[0044]

Although the top plate formed in the shape of a dome is indicated by above-mentioned JP,2002-

299240,A, in the case of-like [dome shape], a resonance location will move greatly radially, the strong location of the plasma will move, and homogeneity will change. On the other hand, in this invention, it differs in the point that homogeneous adjustment can be performed, by collecting plasma a periphery or near a core a top plate 4 by the protruding line 41.

[0045]

Drawing 4 is the sectional view showing the modification of the heights formed in the top plate in other operation gestalten of this invention. the example shown in drawing 4 (a) — a top plate 4 - - the conic projection 42 as heights is mostly formed downward in the main lower part. Since a resonance field can be formed in this example around the core in which the projection 42 was formed, the plasma consistency around a core can be made high, and when field strength is small, it is effective in the circumference of a core of a top plate 4.

[0046]

The example shown in drawing 4 (b) forms the ring-like protruding line 43 around a top plate 4, and forms both a peripheral face and inner skin in the shape of a taper. By forming both a peripheral face and inner skin in the shape of a taper, since the difference of the direction thickness of a path by the side of the top plate of a protruding line 43 and the direction thickness of a path by the side of a head can be enlarged, the resonance field formed around a protruding line 43 can be extended, and the plasma consistency of the circumference of it can be made high.

[0047]

Drawing 4 (c) forms the conic projection 44 which made thickness of the direction of a path thicker than a protruding line 41 in the core other than the protruding line 41 of a periphery shown in drawing 2 . In this example, while forming a resonance field in a periphery by the protruding line 41, even if the microwave of the bigger amplitude than the direction thickness of a path of a protruding line 41 is inputted by forming a resonance field in a core by projection 44, since a resonance field can be constituted from central projection 44, a plasma consistency can be made high in a core.

[0048]

Drawing 5 is the sectional view showing the top plate in which the crevice in the operation gestalt of further others of this invention was formed. The example shown in drawing 5 (a) establishes mostly the circular crevice 401 of a top plate 4 which placed opening upside down in a center section. As for the crevice 401, inner skin is formed in the shape of a taper so that the lower diameter of opening may become large. Heights 402 are formed in that outside of this crevice 401. Since a resonance field can be formed in the thick thick part of heights 402 in this example, the plasma consistency in this part can be made high, and it is effective when the electric-field consistency in the circumference part of a top plate 4 is small.

[0049]

Drawing 5 (b) forms the ring-like crevice 403 in the said alignment with a top plate 4. The peripheral face and inner skin of a crevice 403 are formed in the shape of a taper so that the lower diameter of opening may become large. The downward heights 404 are formed in that inside of this crevice 403, and a protruding line 405 is formed in that outside of it. In this example, since a resonance field can be formed in the thick thick parts of heights 404 and a protruding line 405, the plasma consistency in these parts can be made high.

[0050]

Drawing 5 (c) forms the ring-like crevice 407 in the circular crevice 406 of a top plate 4 which placed opening upside down in the center section mostly, and the outside of a crevice 406. A peripheral face and inner skin are formed in the shape of a taper so that the peripheral face may be formed in the shape of a taper so that the lower diameter of opening may become large, and, as for a crevice 406, the lower diameter of opening may become large like the crevice 403 of drawing 5 (b) as for a crevice 407. In this example, since a protruding line 408 is formed in the outside of a crevice 406, a protruding line 409 is formed in the outside of a crevice 407 and a resonance field can be formed in the thick thick part of protruding lines 408 and 409, the plasma consistency in these parts can be made high.

[0051]

Drawing 6 is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention. This operation gestalt is replaced with the crevice 406 in the example shown in drawing 5 (c), and the ring-like crevice 407, and forms a crevice 410 and the ring-like crevice 411. Although it places opening of the crevices 410 and 411 upside down, the peripheral face of a crevice 410 is formed the shape not of a taper but in the shape of radii, and the peripheral face and inner skin of a crevice 411 are also formed in the shape of radii. Therefore, the shape of radii shall also be included in the shape of [in this invention] a taper.

[0052]

Thus, since a protruding line 412 is formed between a crevice 410 and the ring-like crevice 411 like drawing 5 (c) by forming so that the thickness of a top plate 4 may change in the shape of radii, a protruding line 413 is formed in the outside of a crevice 411 and a resonance field can be formed in these thick thick parts, the plasma consistency in these parts can be made high.

[0053]

In addition, as for the taper-like section formed in a top plate 4, in the operation gestalt shown in drawing 1 - drawing 6 , it is desirable to form outside [at least one] the radius R of a substrate 11, as shown in drawing 7 . The plasma consistency near the edge of a substrate 11 can be prevented from becoming low too much by this.

[0054]

Furthermore, more preferably, when distance between the top plates 4 and substrates 11 which were shown in drawing 7 is set to D, as for the taper-like section formed in a top plate 4, it is desirable to be formed inside [at least one] a radius D from the core of a top plate 4. The plasma near the core of a top plate 4 can be prevented from becoming low too much by this.

[0055]

Drawing 8 is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention. The example shown in drawing 8 (a) forms in the core of a top plate 4 the heights 421 which project downward, and the thickness of the top plate 4 near the outside of these heights 421 is chosen as lambda/4**lambda/8. Furthermore, while forming in the outside of heights 421 the crevice 422 of the shape of a ring which placed opening upside down, the thick thick heights 423 which project downward are formed in the outside of a crevice 422, and the slot 424 of the shape of two or more ring is formed in an underside in the said alignment except for the periphery section of heights 423. The peripheral face of heights 421 and the inner skin of heights 423 are formed in the shape of a taper.

[0056]

In this example, reinforcement can be raised by having formed the thick thick heights 423 in the outside of a crevice 422. Moreover, it becomes easy to emit the outermost periphery in which it can control that that front face to the plasma is emitted by the two or more ring-like slot 424 although the plasma consistency in these heights 423 part becomes high, an electric-field consistency also becomes high and it becomes easy to emit the plasma, and the slot 424 is not formed to the plasma.

[0057]

Furthermore, the crevice 425 is formed in the atmospheric-air side which is the antenna 3 side of a top plate 4. As for this crevice 425, it is desirable for that depth to be formed or more in lambda/8, and to be more preferably formed or more in lambda/4. The matter (not shown) with which dielectric constants differ is arranged in atmospheric air, a good conductor, or a top plate 4 in a crevice 425. Since microwave is strongly reflected near [crevice 425] the core of a top plate 4, this is for improving the trouble that the plasma tends to become strong in this part. If the thickness of the periphery of a crevice 425 is about lambda/4, the effectiveness will be promoted further.

[0058]

In addition, a crevice 425 may be formed around but [not only the core by the side of the antenna 3 of a top plate 4].

[0059]

The example shown in drawing 8 (b) forms the heights 421 which project in the lower part of the core of a top plate 4. The ring-like crevice 422 where opening of the lower part was carried out is formed in the outside of heights 421. A protruding line 426 is formed downward in the outside of a crevice 422, the ring-like crevice 427 where opening of the lower part was further carried out to the outside of a protruding line 426 is formed, and the protruding line 428 of the shape of a ring which projects downward is formed in the outside of a crevice 427. Compared with heights 421 and a protruding line 426, as for the protruding line 428 formed in the outermost periphery, thickness is formed thickly. Moreover, the peripheral face and inner skin of crevices 422 and 427 are formed in the shape of a taper.

[0060]

In this example, the mechanical strength of a top plate 4 can be maintained by having formed the protruding line 426. Moreover, although a resonance field is formed by protruding lines 426 and 428, the plasma consistency in this part can be made high compared with the plasma consistency of a protruding line 426 by forming thickly the thickness of protruding line 428 part of the outermost periphery compared with the protruding line 426.

[0061]

In the example shown in drawing 8 (c), the disc-like heights 429 are formed downward in the center section of the top plate 4, two or more slots 430 are formed in the underside in the said alignment, the crevice 431 of the shape of a ring which placed opening upside down on the outside of heights 429 is formed, and the protruding line 432 which projects downward is formed in the outside of a crevice 431. Compared with heights 429, as for the protruding line 432, thickness is formed thickly. In this example, thickness can be thickened by the heights 429 of the center section of the top plate 4, and a mechanical strength can be raised. Since heights 429 have thick thickness, the plasma becomes is hard to be emitted by forming the fang furrow 430 to which it becomes easy to spread the plasma and a consistency becomes high. And in the thick thin part of a crevice 431, it is hard coming to spread the plasma and the plasma consistency in the protruding line 432 of the outermost periphery can be made high. In addition, also in this example, the crevice 425 is formed in the atmospheric-air side which is the antenna 3 side of a top plate 4 like drawing 8 (a).

[0062]

As other operation gestalten of this invention, drawing 9 forms a protruding line corresponding to the location of the slot of a slot plate. That is, as shown in drawing 9 (a), the slots 31, 32, and 33 arranged in the shape of a ring in Mie are formed on the concentric circle at disc-like slot plate 3c. The microwave inputted into a waveguide 6 is emitted in a chamber 1 through the slots 31, 32, and 33 of slot plate 3c, and electromagnetic field are generated. Therefore, the field strength of the part corresponding to the location of slots 31, 32, and 33 is the largest among top plates 4.

[0063]

Then, as shown in drawing 9 (b), corresponding to each location of each slots 31, 32, and 33, two or more ring-like protruding lines 45, 46, and 47 are formed. Although these protruding lines 45, 46, and 47 have a vertical peripheral face to the underside of a top plate 4 like the protruding line 41 shown in drawing 1 , and they are formed in the shape of a taper so that inner skin may have a predetermined include angle to a top plate 4, a peripheral face side may also be formed in the shape of a taper. The field strength of the part corresponding to each location of each slots 31, 32, and 33 is strong among top plates 4, and the plasma can be made into homogeneity by forming a resonance field in this part.

[0064]

Drawing 10 is drawing which looked at the top plate in which the operation gestalt of further others of this invention is shown from the bottom. To having formed the ring-like protruding lines 45, 46, and 47 corresponding to the location of each slots 31, 32, and 33 of slot plate 3c, corresponding to each location of each slots 31, 32, and 33, each becomes independent and the operation gestalt shown in above-mentioned drawing 9 (b) arranges much projections 48 of the shape of small **** of a path with this operation gestalt. Also in this operation gestalt, resonance can be distributed for the strong field strength produced in each slots 31, 32, and 33

by much projections 48.
[0065]
In this invention, the thickness of a top plate 4 can generate the plasma stabilized even when the pressure as plasma conditions (for example, the plasma) changed to 1 - 100Torr when the diameter of a protruding line 41 forms [the diameter of a top plate 4] projection height in 22mm by 220mm by 280mm, and the output of microwave changed 100-3000W in 21mm.
[0066]
Although 1 operation gestalt of this invention was explained with reference to the drawing, this invention is not limited to the illustrated operation gestalt. It is possible to add various modification to the operation gestalt illustrated within equal limits within the same limits as this invention.
[Availability on industry]
[0067]
The top plate 4 which closes opening of a chamber 1 in the lower part of the antenna section 3 which drives by microwave and generates electromagnetic field is formed. It can use for the plasma treatment equipment which can generate the plasma stabilized covering the low pressure from the high pressure by forming the ring-like protruding line 41 in the underside side of a top plate 4, changing the thickness of the direction of a path continuously in the shape of a taper, and resonating it by somewhere in every condition of the plasma.
[Brief Description of the Drawings]
[0068]
[Drawing 1] It is the sectional view of the plasma treatment equipment in 1 operation gestalt of this invention.
[Drawing 2] It is drawing which looked at the top plate shown in drawing 1 from the underside. .
[Drawing 3] It is drawing for explaining the condition that microwave spreads the inside of a top plate.
[Drawing 4] It is the sectional view showing the modification of the heights formed in the top plate in other operation gestalten of this invention.
[Drawing 5] It is the sectional view showing the crevice formed in the top plate in other operation gestalten of this invention.
[Drawing 6] It is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention.
[Drawing 7] It is drawing for explaining the location of the top plate which forms heights or a crevice.
[Drawing 8] It is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention.
[Drawing 9] It is drawing showing the example in which the protruding line was formed in a top plate as other operation gestalten of this invention corresponding to the slot of a slot plate.
[Drawing 10] It is drawing which looked at the top plate in which the operation gestalt of further others of this invention is shown from the bottom.
[Drawing 11] It is the sectional view showing an example of conventional plasma treatment equipment.
[Drawing 12] It is drawing showing the field strength distribution depending on the thickness of a top plate.
[Description of Notations]
[0069]
1 Chamber, 3 Antenna Section, 3B Slow Wave Plate, 3C Slot Plate, 4 A top plate, 6 A waveguide, 7 A susceptor, 10 Cooling plate, 11 A substrate, 22 A plasma production field, 31-33 Slot, 41, 43, 45-47, 405, 408, 409, 412, 413,426,428,432 Protruding line, 42, 44, 48 A projection, 401, 403, 406, 407, 410, 411, 422,425,427,431 A crevice, 402, 404, 408, 413,421,423,429 Heights, 424,430 Slot.

[Translation done.]

* NOTICES *

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TECHNICAL FIELD

[Field of the Invention]
[0001]
Especially this invention relates to the plasma treatment equipment which generates the plasma in a chamber by emitting the microwave supplied to the antenna about plasma treatment equipment through the top plate which consists of a dielectric which closes opening in a chamber.

[Translation done.]

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PRIOR ART

[Background of the Invention]
[0002]
In recent years, with the densification of a semiconductor device, and detailed-izing, in the production process of a semiconductor device, in order to process membrane formation, etching, ashing, etc., plasma treatment equipment is used. With the microwave plasma treatment equipment made to generate the plasma especially using microwave, he can feel easy also under the about 0.1-10Pa conditions that a pressure is comparatively low (high vacuum), and can generate the plasma. Therefore, the microwave plasma treatment equipment using microwave with a frequency of 2.45GHz attracts attention, for example.
[0003]
Drawing 11 is the sectional view showing an example of such conventional plasma treatment equipment. Plasma treatment equipment is equipped with the chamber 1 for holding a substrate 11 and performing predetermined processing to a substrate 11, RF generator 5 for generating microwave, and the antenna section 3 for emitting microwave in a chamber 1 in drawing 11 .
[0004]
The antenna section 3 has slot plate 3c, slow wave plate 3b, and antenna covering 3a, and is constituted. Two or more slots (opening) for turning and emitting microwave in a chamber 1 are formed in slot plate 3c. The microwave generated by RF generator 5 is sent to the antenna section 3 by the waveguide 6. The top plate 4 which constitutes some septa of a chamber 1 is arranged in the upper part of a chamber 1, and the seal members 14, such as an O ring, are formed between the top plate 4 and the septum of a chamber 1. The antenna section 3 is arranged above this top plate 4.
[0005]
In the chamber 1, the susceptor 7 for holding the contained substrate 11 is formed. Furthermore, the vacuum pump 9 for exhausting the inside of a chamber 1 is connected to the chamber 1. The inside of a chamber 1 is exhausted by this vacuum pump 9, and for example, argon gas is introduced in a chamber 1 as gas for generating the plasma under a predetermined pressure range.
[0006]
With above-mentioned plasma equipment, the microwave generated by RF generator 5 reaches propagation and the antenna section 3 in a waveguide 6. The microwave which reached the antenna section 3 spreads slow wave plate 3b, and is radiated on a top plate 4 through slot plate 3c. In a top plate 4, microwave produces an oscillation in the direction of a field, is spread towards a periphery from a core, and generates electromagnetic field in a chamber 1. Of the electromagnetic field generated in the chamber 1, argon gas dissociates, the plasma production field 22 is formed between a substrate 11 and a top plate 4, and predetermined plasma treatment is performed to a substrate 11.
[0007]
In such plasma treatment equipment, it is necessary to irradiate [a substrate 11] the plasma at homogeneity. However, by the core and periphery of a top plate 4, since plasma reinforcement differs, by forming a top plate 4 in a concave surface configuration, and making distance with the

periphery of a substrate 11 and a top plate 4 approach in JP,2002-299240,A, lowering of the plasma consistency in the periphery of a substrate 11 is compensated, the plasma is maintained also in low voltage processing, and making stable plasma treatment possible is indicated.
[0008]
Moreover, forming a ring-like sleeve in JP,2003-59919,A so that a plasma excitation field may not contact a dielectric window with the surface of metal of a direct-processing vessel wall, and obtaining a uniform plasma consistency on a substrate front face is indicated.
[Patent reference 1] JP,2002-299240,A
[Patent reference 2] JP,2003-59919,A

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]
[0009]
Plasma equipment requires a certain amount of [in the direction of a field] thickness as a top plate 4, in order to oppose the force which secures reinforcement in the chamber 1 by which the interior is decompressed, and the open air pushes. A resonance field is formed in a dielectric of microwave, strong electric field occur, a standing wave is formed [a top plate 4 is constituted by the dielectric,], electromagnetic field are produced in a chamber 1 by this standing wave, and a plasma consistency becomes high. There is thickness of the dielectric suitable for making a standing wave.
[0010]
Drawing 12 is drawing showing the field strength distribution depending on the thickness of a top plate. Drawing 12 (a) is a part to which the part which shows field strength distribution in case the thickness of the direction of a field of a top plate 4 is 22.8mm, and is shown with a main slash is strong [field strength]. Drawing 12 (b) shows the field strength distribution when setting thickness of a top plate 4 to 27.8mm, and field strength distribution is spreading on the outskirts from a core compared with drawing 12 (a). Drawing 12 (c) shows the field strength distribution when setting thickness of a top plate 4 to 31.6mm, and field strength distribution is distributed to the circumference except for a part for the core of a top plate 4, and has thickness for which were most suitable. Drawing 12 (d) shows the field strength distribution when setting thickness of a top plate 4 to 32.8mm, and, only as for the core, field strength distribution is strong. Drawing 12 (e) shows the field strength distribution when setting thickness of a top plate 4 to 37.8mm, and the field strength of a core is strong.
[0011]
In the plasma treatment equipment shown in drawing 11 , since the electron density near the plasma front face will change if plasma conditions, such as a pressure in a chamber 1 and power of microwave, are made to change, the trespass depth by which the plasma invades into the matter changes. Since a diffusion coefficient will increase if a pressure is reduced, the electron density near a plasma front face falls, and trespass depth increases. Thus, since the suitable thickness of a dielectric will change if plasma conditions are changed, the resonance field for forming a standing wave will shift. For this reason, in order to generate the plasma in the always optimal condition, there was a problem that it was necessary to prepare the dielectric which has the various thickness according to plasma conditions. Moreover, the absorption efficiency of microwave to the plasma in the low voltage force is bad, and the generation by which the plasma in low voltage (20mTorr) was stabilized becomes difficult.
[0012]
So, the object of this invention is offering the plasma treatment equipment which can generate the plasma which formed the resonance field optimal in a top plate according to plasma conditions, and was stabilized in the chamber covering the low pressure from the high pressure.

[Translation done.]

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MEANS

[Means for Solving the Problem]
[0013]
This invention is characterized by to have the antenna which contains a processed substrate, is arranged at opening of the upper part of the plasma generating room which generates the plasma, and a plasma generating room, drives by microwave, and generates electromagnetic field, the top plate which is formed in the lower part of an antenna, have uniform predetermined thickness in the direction of a field, and close opening of a plasma generating room, and taper-like the heights or the crevice formed in the underside side of a top plate.
[0014]
In this invention, by the taper-like part of the heights formed in the top plate, or a crevice, change the thickness of the direction of a path continuously, it is made to resonate by somewhere in every condition of the plasma, and the optimal resonance field can be formed. Therefore, the effectiveness same with having prepared the top plate of various thickness can be done so only by preparing one kind of top plate. Thereby, the absorption efficiency to the plasma can be raised by leaps and bounds, and generating of the plasma stabilized covering the low pressure from the high pressure is attained.

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EXAMPLE

[Example]
[0031]
Drawing 1 is the sectional view of the plasma treatment equipment in 1 operation gestalt of this invention, and drawing 2 is drawing which looked at the dielectric plate shown in drawing 1 from the underside.
[0032]
Plasma treatment equipment is equipped with the chamber 1 for holding a substrate 11 and performing predetermined processing to a substrate 11 like above-mentioned drawing 11 , and the antenna section 3 for emitting microwave in a chamber 1.
[0033]
The microwave generated by the RF generator which is not illustrated is sent to the antenna section 3 by the waveguide 6. The top plate 4 which closes opening of a chamber 1 and constitutes some septa of a chamber 1 is arranged in the upper part of a chamber 1, and the seal members 14, such as an O ring, are formed between the top plate 4 and the septum of a chamber 1. The antenna section 3 is arranged above this top plate 4. The cooling plate 10 with which a refrigerant flows is formed in the interior in the upper part of the antenna section 3.
[0034]
In the chamber 1, the susceptor 7 for holding the contained substrate 11 is formed. The susceptor 7 has the heater ability for heating a substrate 11. Furthermore, in order to exhaust the inside of a chamber 1, the vacuum pump shown in drawing 11 is connected to the chamber 1. The inside of a chamber 1 is exhausted by this vacuum pump, and for example, argon gas is introduced in a chamber 1 as gas for generating the plasma under a predetermined pressure range.
[0035]
With above-mentioned plasma equipment, the microwave generated by the RF generator reaches propagation and the antenna section 3 in a waveguide 6. The microwave which reached the antenna section 3 spreads slow wave plate 3b, forms a resonance field in a top plate 4 through slot plate 3c, generates a standing wave, and generates electromagnetic field in a chamber 1. Of the electromagnetic field generated in the chamber 1, argon gas dissociates, the plasma production field 22 is formed between a substrate 11 and a top plate 4, and predetermined plasma treatment is performed to a substrate 11.
[0036]
The top plate 4 is formed in the direction of a field disc-like [which has uniform predetermined thickness], in order to oppose the force which secures reinforcement and the open air pushes, and heights or a crevice is formed in the underside. Predetermined spacing is separated from the periphery of a top plate 4 in the direction of a path as heights or a crevice, and, more specifically, the ring-like protruding line 41 is formed in the periphery in the said alignment with the core of a top plate 4. A peripheral face is vertical to the underside of a top plate 4, and inner skin is formed in the shape of a taper so that it may have a predetermined include angle to a top plate 4, and as for this protruding line 41, the cross section forms rectangular heights or a rectangular crevice. Microwave is supplied to the top plate 4 from the antenna section 3, and it

has become a non-dense to the plasma consistency of a core being dense to form a protruding line 41 in the periphery of a top plate 4 by the periphery, and it is for raising the plasma consistency of a periphery.

[0037]

Drawing 3 is drawing for explaining the condition that microwave spreads the inside of a top plate. Although the thick thick part and the other thick thin part are contained by the protruding line 41, microwave stops being able to spread a top plate 4 easily due to the thick thin part of a top plate 4 by choosing the thickness of a thick thin part as lambda/4**lambda/8.

[0038]

If the reason is explained, Mode A and Mode B exist in the gestalt of the electromagnetic wave which passes through the inside of a top plate. Since Mode A exists if electron density becomes beyond a predetermined value, and Mode B exists only when electron density is comparatively small, when electron density is high to some extent, the microwave propagation by Mode B is controlled.

[0039]

However, this is greatly dependent on top-plate thickness, and by lambda/4 or more thickness, the minimum of the electron density which can control propagation with Mode B will become high, so that it becomes thick. If it becomes lambda/2 or more, since Mode B can be existed without being dependent on electron density, it becomes impossible to control propagation with Mode B. On the contrary, the minimum of the electron density which can control propagation with Mode B does not change or less by lambda/4. Therefore, if the reinforcement of a top plate is taken into consideration, lambda/4 will become the optimal. However, if it is the range of ** lambda/8, propagation with Mode B can be controlled almost.

[0040]

Although the microwave supplied to the antenna section 3 is emitted to down from the slot of the antenna section 3, as shown in drawing 3 , it is reflected within a top plate 4, and it vibrates in the direction of a field by the repeat of the echo in a top plate 4, and it forms a resonance field, and turns into a standing wave. (Though it is explanation of being hard to spread in a thick thin part, it is illustrated so that microwave may spread in the direction of a path in drawing 3 , and it is thought that it is inconsistent.) Please give supplementary information. Since it is hard coming to come out the microwave included in the protruding line section 41 to the plasma production field 22, microwave becomes is easy to be accumulated in the protruding line part 41. Thereby, the plasma consistency of the periphery by having formed the protruding line 41 can be raised. Protruding line 41 part constitutes a resonance field from a periphery of a top plate 4, and vibrates in the direction of a path in which microwave intersects perpendicularly in the direction of a field of a top plate 4.

[0041]

Since the protruding line 41 is formed in the shape of a taper to the thing with the thick direction thickness of a path by the side of a top plate 4 so that the direction thickness of a path by the side of a head may become thin, the part whose thickness of the amplitude and protruding line 41 which vibrate in the direction of a path corresponds surely exists. That is, since a protruding line 41 constitutes a resonance field in the periphery of a top plate 4 and a resonance field goes up and down it automatically according to a plasma consistency, the place which resonates by somewhere in every condition of the plasma exists.

[0042]

Since the optimal resonance field for a top plate 4 can be formed by this, strong electric field are generated, a standing wave can be formed, a plasma consistency can be made high, and generating of the plasma stabilized covering the low pressure from the high pressure is attained.

[0043]

In addition, this protruding line 41 may form a peripheral face and inner skin side in the shape of a taper. Moreover, what is necessary is just to choose as arbitration the location or configuration which arranges a protruding line 41 according to the thickness of a top plate 4.

[0044]

Although the top plate formed in the shape of a dome is indicated by above-mentioned JP,2002-

299240,A, in the case of-like [dome shape], a resonance location will move greatly radially, the strong location of the plasma will move, and homogeneity will change. On the other hand, in this invention, it differs in the point that homogeneous adjustment can be performed, by collecting plasma a periphery or near a core a top plate 4 by the protruding line 41.

[0045]

Drawing 4 is the sectional view showing the modification of the heights formed in the top plate in other operation gestalten of this invention. the example shown in drawing 4 (a) — a top plate 4 - - the conic projection 42 as heights is mostly formed downward in the main lower part. Since a resonance field can be formed in this example around the core in which the projection 42 was formed, the plasma consistency around a core can be made high, and when field strength is small, it is effective in the circumference of a core of a top plate 4.

[0046]

The example shown in drawing 4 (b) forms the ring-like protruding line 43 around a top plate 4, and forms both a peripheral face and inner skin in the shape of a taper. By forming both a peripheral face and inner skin in the shape of a taper, since the difference of the direction thickness of a path by the side of the top plate of a protruding line 43 and the direction thickness of a path by the side of a head can be enlarged, the resonance field formed around a protruding line 43 can be extended, and the plasma consistency of the circumference of it can be made high.

[0047]

Drawing 4 (c) forms the conic projection 44 which made thickness of the direction of a path thicker than a protruding line 41 in the core other than the protruding line 41 of a periphery shown in drawing 2 . In this example, while forming a resonance field in a periphery by the protruding line 41, even if the microwave of the bigger amplitude than the direction thickness of a path of a protruding line 41 is inputted by forming a resonance field in a core by projection 44, since a resonance field can be constituted from central projection 44, a plasma consistency can be made high in a core.

[0048]

Drawing 5 is the sectional view showing the top plate in which the crevice in the operation gestalt of further others of this invention was formed. The example shown in drawing 5 (a) establishes mostly the circular crevice 401 of a top plate 4 which placed opening upside down in a center section. As for the crevice 401, inner skin is formed in the shape of a taper so that the lower diameter of opening may become large. Heights 402 are formed in that outside of this crevice 401. Since a resonance field can be formed in the thick thick part of heights 402 in this example, the plasma consistency in this part can be made high, and it is effective when the electric-field consistency in the circumference part of a top plate 4 is small.

[0049]

Drawing 5 (b) forms the ring-like crevice 403 in the said alignment with a top plate 4. The peripheral face and inner skin of a crevice 403 are formed in the shape of a taper so that the lower diameter of opening may become large. The downward heights 404 are formed in that inside of this crevice 403, and a protruding line 405 is formed in that outside of it. In this example, since a resonance field can be formed in the thick thick parts of heights 404 and a protruding line 405, the plasma consistency in these parts can be made high.

[0050]

Drawing 5 (c) forms the ring-like crevice 407 in the circular crevice 406 of a top plate 4 which placed opening upside down in the center section mostly, and the outside of a crevice 406. A peripheral face and inner skin are formed in the shape of a taper so that the peripheral face may be formed in the shape of a taper so that the lower diameter of opening may become large, and, as for a crevice 406, the lower diameter of opening may become large like the crevice 403 of drawing 5 (b) as for a crevice 407. In this example, since a protruding line 408 is formed in the outside of a crevice 406, a protruding line 409 is formed in the outside of a crevice 407 and a resonance field can be formed in the thick thick part of protruding lines 408 and 409, the plasma consistency in these parts can be made high.

[0051]

Drawing 6 is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention. This operation gestalt is replaced with the crevice 406 in the example shown in drawing 5 (c), and the ring-like crevice 407, and forms a crevice 410 and the ring-like crevice 411. Although it places opening of the crevices 410 and 411 upside down, the peripheral face of a crevice 410 is formed the shape not of a taper but in the shape of radii, and the peripheral face and inner skin of a crevice 411 are also formed in the shape of radii. Therefore, the shape of radii shall also be included in the shape of [in this invention] a taper.

[0052]

Thus, since a protruding line 412 is formed between a crevice 410 and the ring-like crevice 411 like drawing 5 (c) by forming so that the thickness of a top plate 4 may change in the shape of radii, a protruding line 413 is formed in the outside of a crevice 411 and a resonance field can be formed in these thick thick parts, the plasma consistency in these parts can be made high.

[0053]

In addition, as for the taper-like section formed in a top plate 4, in the operation gestalt shown in drawing 1 - drawing 6 , it is desirable to form outside [at least one] the radius R of a substrate 11, as shown in drawing 7 . The plasma consistency near the edge of a substrate 11 can be prevented from becoming low too much by this.

[0054]

Furthermore, more preferably, when distance between the top plates 4 and substrates 11 which were shown in drawing 7 is set to D, as for the taper-like section formed in a top plate 4, it is desirable to be formed inside [at least one] a radius D from the core of a top plate 4. The plasma near the core of a top plate 4 can be prevented from becoming low too much by this.

[0055]

Drawing 8 is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention. The example shown in drawing 8 (a) forms in the core of a top plate 4 the heights 421 which project downward, and the thickness of the top plate 4 near the outside of these heights 421 is chosen as lambda/4**lambda/8. Furthermore, while forming in the outside of heights 421 the crevice 422 of the shape of a ring which placed opening upside down, the thick thick heights 423 which project downward are formed in the outside of a crevice 422, and the slot 424 of the shape of two or more ring is formed in an underside in the said alignment except for the periphery section of heights 423. The peripheral face of heights 421 and the inner skin of heights 423 are formed in the shape of a taper.

[0056]

In this example, reinforcement can be raised by having formed the thick thick heights 423 in the outside of a crevice 422. Moreover, it becomes easy to emit the outermost periphery in which it can control that that front face to the plasma is emitted by the two or more ring-like slot 424 although the plasma consistency in these heights 423 part becomes high, an electric-field consistency also becomes high and it becomes easy to emit the plasma, and the slot 424 is not formed to the plasma.

[0057]

Furthermore, the crevice 425 is formed in the atmospheric-air side which is the antenna 3 side of a top plate 4. As for this crevice 425, it is desirable for that depth to be formed or more in lambda/8, and to be more preferably formed or more in lambda/4. The matter (not shown) with which dielectric constants differ is arranged in atmospheric air, a good conductor, or a top plate 4 in a crevice 425. Since microwave is strongly reflected near [crevice 425] the core of a top plate 4, this is for improving the trouble that the plasma tends to become strong in this part. If the thickness of the periphery of a crevice 425 is about lambda/4, the effectiveness will be promoted further.

[0058]

In addition, a crevice 425 may be formed around but [not only the core by the side of the antenna 3 of a top plate 4].

[0059]

The example shown in drawing 8 (b) forms the heights 421 which project in the lower part of the core of a top plate 4. The ring-like crevice 422 where opening of the lower part was carried out is formed in the outside of heights 421. A protruding line 426 is formed downward in the outside of a crevice 422, the ring-like crevice 427 where opening of the lower part was further carried out to the outside of a protruding line 426 is formed, and the protruding line 428 of the shape of a ring which projects downward is formed in the outside of a crevice 427. Compared with heights 421 and a protruding line 426, as for the protruding line 428 formed in the outermost periphery, thickness is formed thickly. Moreover, the peripheral face and inner skin of crevices 422 and 427 are formed in the shape of a taper.

[0060]

In this example, the mechanical strength of a top plate 4 can be maintained by having formed the protruding line 426. Moreover, although a resonance field is formed by protruding lines 426 and 428, the plasma consistency in this part can be made high compared with the plasma consistency of a protruding line 426 by forming thickly the thickness of protruding line 428 part of the outermost periphery compared with the protruding line 426.

[0061]

In the example shown in drawing 8 (c), the disc-like heights 429 are formed downward in the center section of the top plate 4, two or more slots 430 are formed in the underside in the said alignment, the crevice 431 of the shape of a ring which placed opening upside down on the outside of heights 429 is formed, and the protruding line 432 which projects downward is formed in the outside of a crevice 431. Compared with heights 429, as for the protruding line 432, thickness is formed thickly. In this example, thickness can be thickened by the heights 429 of the center section of the top plate 4, and a mechanical strength can be raised. Since heights 429 have thick thickness, the plasma becomes is hard to be emitted by forming the fang furrow 430 to which it becomes easy to spread the plasma and a consistency becomes high. And in the thick thin part of a crevice 431, it is hard coming to spread the plasma and the plasma consistency in the protruding line 432 of the outermost periphery can be made high. In addition, also in this example, the crevice 425 is formed in the atmospheric-air side which is the antenna 3 side of a top plate 4 like drawing 8 (a).

[0062]

As other operation gestalten of this invention, drawing 9 forms a protruding line corresponding to the location of the slot of a slot plate. That is, as shown in drawing 9 (a), the slots 31, 32, and 33 arranged in the shape of a ring in Mie are formed on the concentric circle at disc-like slot plate 3c. The microwave inputted into a waveguide 6 is emitted in a chamber 1 through the slots 31, 32, and 33 of slot plate 3c, and electromagnetic field are generated. Therefore, the field strength of the part corresponding to the location of slots 31, 32, and 33 is the largest among top plates 4.

[0063]

Then, as shown in drawing 9 (b), corresponding to each location of each slots 31, 32, and 33, two or more ring-like protruding lines 45, 46, and 47 are formed. Although these protruding lines 45, 46, and 47 have a vertical peripheral face to the underside of a top plate 4 like the protruding line 41 shown in drawing 1 , and they are formed in the shape of a taper so that inner skin may have a predetermined include angle to a top plate 4, a peripheral face side may also be formed in the shape of a taper. The field strength of the part corresponding to each location of each slots 31, 32, and 33 is strong among top plates 4, and the plasma can be made into homogeneity by forming a resonance field in this part.

[0064]

Drawing 10 is drawing which looked at the top plate in which the operation gestalt of further others of this invention is shown from the bottom. To having formed the ring-like protruding lines 45, 46, and 47 corresponding to the location of each slots 31, 32, and 33 of slot plate 3c, corresponding to each location of each slots 31, 32, and 33, each becomes independent and the operation gestalt shown in above-mentioned drawing 9 (b) arranges much projections 48 of the shape of small **** of a path with this operation gestalt. Also in this operation gestalt, resonance can be distributed for the strong field strength produced in each slots 31, 32, and 33

by much projections 48.

[0065]

In this invention, the thickness of a top plate 4 can generate the plasma stabilized even when the pressure as plasma conditions (for example, the plasma) changed to 1 - 100Torr when the diameter of a protruding line 41 forms [the diameter of a top plate 4] projection height in 22mm by 220mm by 280mm, and the output of microwave changed 100-3000W in 21mm.

[0066]

Although 1 operation gestalt of this invention was explained with reference to the drawing, this invention is not limited to the illustrated operation gestalt. It is possible to add various modification to the operation gestalt illustrated within equal limits within the same limits as this invention.

[Translation done.]

* NOTICES *

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2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[0068]
[Drawing 1] It is the sectional view of the plasma treatment equipment in 1 operation gestalt of this invention.
[Drawing 2] It is drawing which looked at the top plate shown in drawing 1 from the underside. .
[Drawing 3] It is drawing for explaining the condition that microwave spreads the inside of a top plate.
[Drawing 4] It is the sectional view showing the modification of the heights formed in the top plate in other operation gestalten of this invention.
[Drawing 5] It is the sectional view showing the crevice formed in the top plate in other operation gestalten of this invention.
[Drawing 6] It is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention.
[Drawing 7] It is drawing for explaining the location of the top plate which forms heights or a crevice.
[Drawing 8] It is the sectional view showing the modification of the crevice formed in the top plate in the operation gestalt of further others of this invention.
[Drawing 9] It is drawing showing the example in which the protruding line was formed in a top plate as other operation gestalten of this invention corresponding to the slot of a slot plate.
[Drawing 10] It is drawing which looked at the top plate in which the operation gestalt of further others of this invention is shown from the bottom.
[Drawing 11] It is the sectional view showing an example of conventional plasma treatment equipment.
[Drawing 12] It is drawing showing the field strength distribution depending on the thickness of a top plate.

[Translation done.]

* NOTICES *

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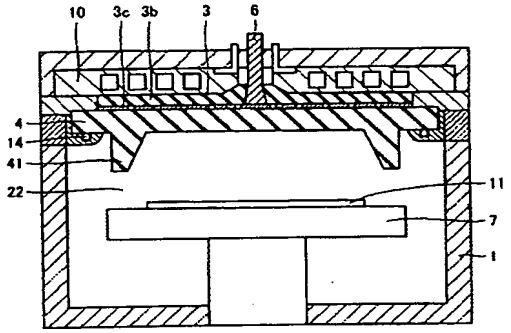
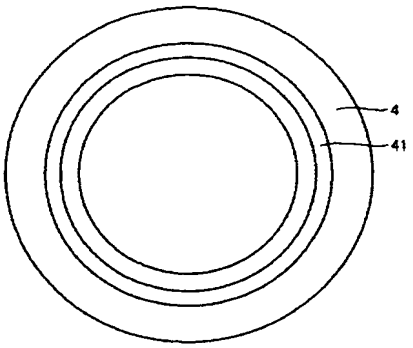
DRAWINGS

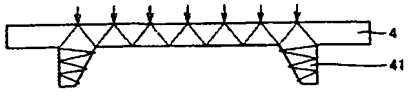
[Drawing 1]



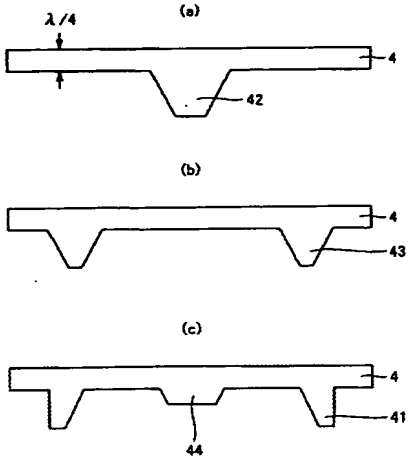
[Drawing 2]



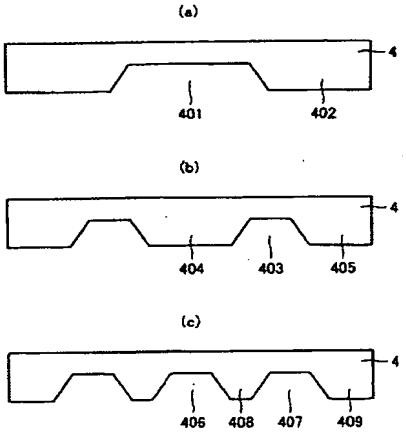
[Drawing 3]



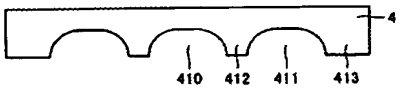
[Drawing 4]



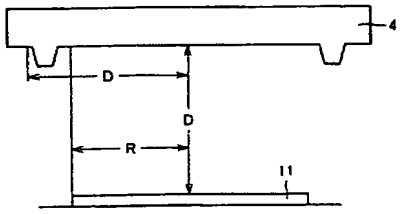
[Drawing 5]



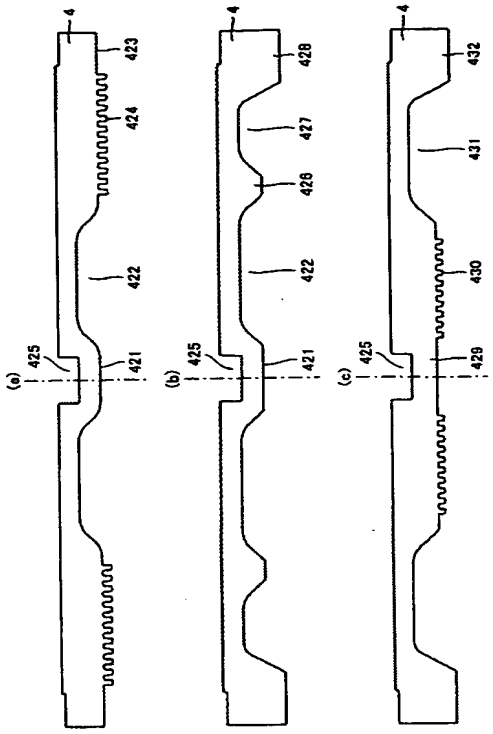
[Drawing 6]



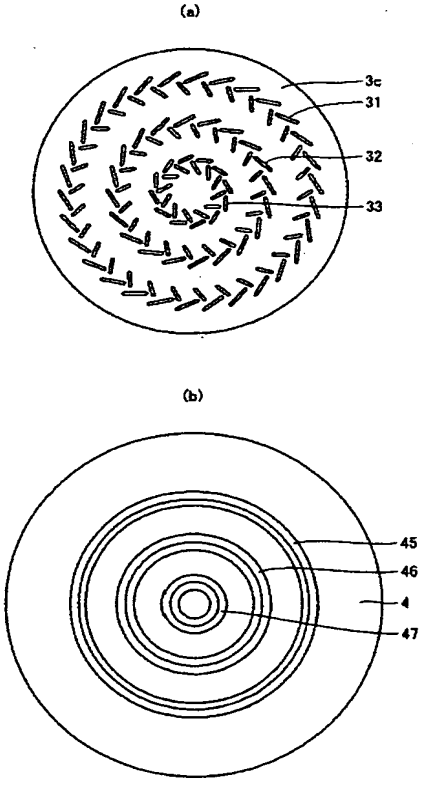
[Drawing 7]



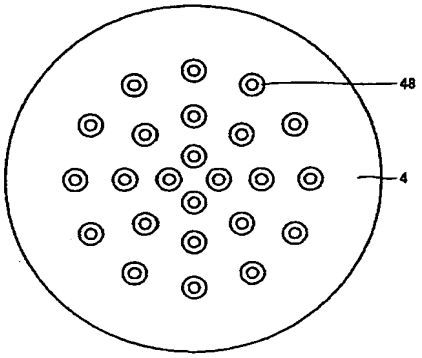
[Drawing 8]


4
423
424
422
425
421
(a)
4
428
427
426
422
425
421
(b)
4
432
431
430
425
429
(c)

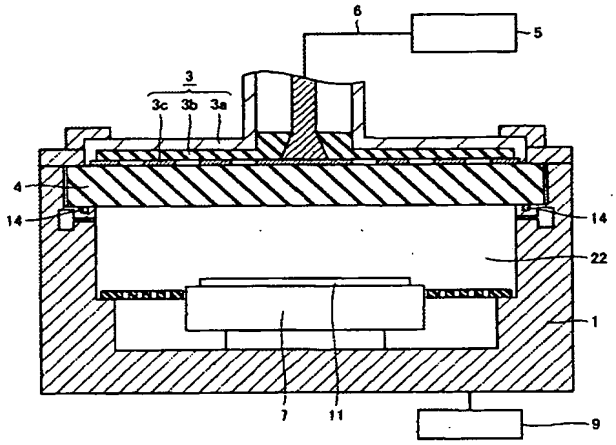
[Drawing 9]


(a)
3c
31
32
33
(b)
45
46
4
47

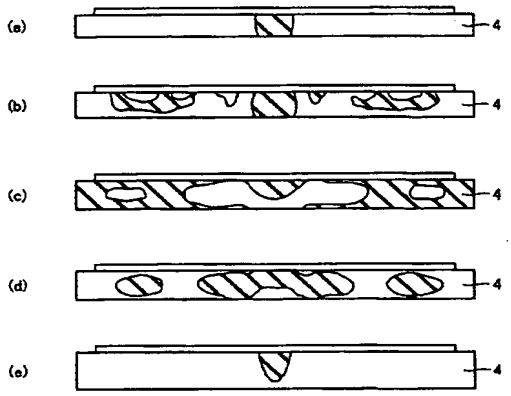
[Drawing 10]



[Drawing 11]



[Drawing 12]



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（出願人による申告）国等の委託研究の成果に係る特許出願（平成１５年度新エネルギー・産業技術総合開発機構「マイクロ波励起高密度プラズマ技術を用いた半導体製造装置の技術開発」委託研究、産業活力再生特別措置法第３０条の適用を受けるもの）

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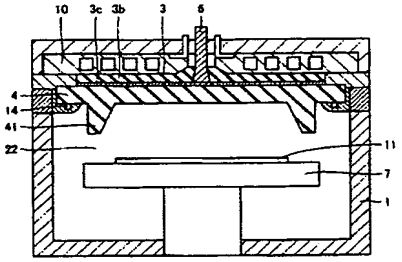
Ｆターム(参考)　4K030 FA01　KA15　KA45　KA46

(54)【発明の名称】プラズマ処理装置

(57)【要約】
【課題】　プラズマ条件に応じて天板内に最適な共振領域を形成し、高い圧力から低い圧力にわたって安定したプラズマの発生が可能なプラズマ処理装置を提供する。
【解決手段】　チャンバー１の上部の開口部に配置されてマイクロ波によって駆動されて電磁界を発生するアンテナ部３を配置し、アンテナ部３の下部にチャンバー１の開口部を封止する天板４を設け、天板４の下面側にリング状の突条４１を設けて径方向の厚さをテーパ状に連続的に変化させることにより、プラズマのどの条件においてもどこかで共振させることができる。これにより、１種類の天板を用意するだけで種々の厚さの天板を用意したのと同様の効果を奏することができ、プラズマへの吸収効率を飛躍的に向上させることができ、高い圧力から低い圧力にわたって安定したプラズマの発生が可能になる。
【選択図】　図１



【特許請求の範囲】
【請求項１】
被処理基板を収納し、プラズマを発生するプラズマ発生室と、
前記プラズマ発生室の上部の開口部に配置され、マイクロ波によって駆動されて電磁界を発生するアンテナと、
前記アンテナの下部に設けられ、面方向に均一な所定の厚さを有して前記プラズマ発生室の開口部を封止する天板と、
前記天板の下面側に形成されたテーパ状の凸部または凹部とを備えた、プラズマ処理装置。
【請求項２】
前記天板は、前記凸部または凹部により肉厚の薄い部分と厚い部分とを含み、
前記肉厚の薄い部分の厚みはλ／４±λ／８に選ばれている、請求項１に記載のプラズマ処理装置。
【請求項３】
前記凸部または凹部は、前記天板の下面にリング状に形成される突条を含む、請求項１または２に記載のプラズマ処理装置。
【請求項４】
前記天板は円板状であって、
前記突条は、前記天板の中心と同心的に径方向に複数形成される、請求項３に記載のプラズマ処理装置。
【請求項５】
前記突条は前記天板側の径方向厚さが先端側の径方向厚さよりも厚く形成される、請求項３または４に記載のプラズマ処理装置。
【請求項６】
前記凸部または凹部は、前記天板の下面に形成される円錐状の突起を含む、請求項１から３のいずれかに記載のプラズマ処理装置。
【請求項７】
前記円錐状の突起は、前記天板の中心下面に形成される、請求項６に記載のプラズマ処理装置。
【請求項８】
前記円錐状の突起は複数設けられ、前記複数の円錐状の突起はリング状に配置される、請求項６に記載のプラズマ処理装置。
【請求項９】
前記凸部または凹部は、前記複数のリング状の凹部と、前記複数のリング状凹部の間に形成される下向きの第１の突条と、最外周のリング状凹部の外側に形成される下向きの第２の突条とを含む、請求項８に記載のプラズマ処理装置。
【請求項１０】
前記第２の凸部の肉厚は、前記第１の凸部の肉厚に比べて厚く形成される、請求項９に記載のプラズマ処理装置。
【請求項１１】
前記天板のアンテナ側の中心部には凹部が形成されており、前記凹部には前記天板の誘電率と異なる物質が配置される、請求項１から１０のいずれかに記載のプラズマ処理装置。
【請求項１２】
前記天板の凹部の深さはλ／８以上の深さに形成される、請求項１１に記載のプラズマ処理装置。
【請求項１３】
前記天板の凹部の深さはλ／４以上の深さに形成される、請求項１１に記載のプラズマ処理装置。
【請求項１４】

前記凸部は、前記天板の前記被処理基板側の中心部に形成され、前記凸部の周辺における天板の肉厚はλ／４±λ／８である、請求項１から１３のいずれかに記載のプラズマ処理装置。

【請求項１５】

前記被処理基板は円板状であって、

前記凸部または凹部は、前記被処理基板の半径をＲとしたとき、前記天板の中心から半径Ｒより外側に少なくとも１つ形成されている、請求項１から１４のいずれかに記載のプラズマ処理装置。

【請求項１６】

前記凸部または凹部は、前記天板と前記被処理基板との距離をＤとしたとき、前記天板の中心から半径Ｄより内側に少なくとも１つ形成されている、請求項１から１５のいずれかに記載のプラズマ処理装置。

【請求項１７】

前記アンテナは、面上にスロットが分布して形成されたスロット板を含み、

前記天板には前記スロット板上のスロットの位置に対応して前記凸部または凹部が形成される、請求項１から３のいずれかに記載のプラズマ処理装置。

【発明の詳細な説明】

【技術分野】

【０００１】

この発明はプラズマ処理装置に関し、特に、アンテナに供給したマイクロ波をチャンバー内の開口部を封止する誘電体からなる天板を介して放射することにより、チャンバー内にプラズマを発生するプラズマ処理装置に関する。

【背景技術】

【０００２】

近年、半導体装置の高密度化および微細化に伴って、半導体装置の製造工程において、成膜，エッチング，アッシングなどの処理を施すためにプラズマ処理装置が使用されている。特に、マイクロ波を用いてプラズマを発生させるマイクロ波プラズマ処理装置では，約０．１～１０Ｐａの比較的圧力が低い（高真空）条件のもとでも安心してプラズマを発生させることができる。そのため、例えば周波数２．４５ＧＨｚのマイクロ波を用いたマイクロ波プラズマ処理装置が注目されている。

【０００３】

図１１はそのような従来のプラズマ処理装置の一例を示す断面図である。図１１において、プラズマ処理装置は、基板１１を収容して基板１１に所定の処理を施すためのチャンバー１と、マイクロ波を発生するための高周波電源５と、マイクロ波をチャンバー１内に放射するためのアンテナ部３とを備えている。

【０００４】

アンテナ部３はスロット板３ｃと遅波板３ｂとアンテナカバー３ａとを有して構成されている。スロット板３ｃには、マイクロ波をチャンバー１内に向けて放射するための複数のスロット（開口部）が形成されている。高周波電源５によって発生されたマイクロ波は、導波管６によりアンテナ部３へ送られる。チャンバー１の上部にはチャンバー１の隔壁の一部を構成する天板４が配設されており、天板４とチャンバー１の隔壁との間には例えばＯリングなどのシール部材１４が設けられている。アンテナ部３はこの天板４の上方に配置されている。

【０００５】

チャンバー１内には、収納された基板１１を保持するためのサセプタ７が設けられている。さらに、チャンバー１には、チャンバー１内を排気するための真空ポンプ９が接続されている。この真空ポンプ９によってチャンバー１内が排気されて、所定の圧力範囲の下でプラズマを生成するためのガスとして例えばアルゴンガスがチャンバー１内に導入される。

【０００６】

上述のプラズマ装置では、高周波電源５により発生したマイクロ波は導波管６を伝わり、アンテナ部３に到達する。アンテナ部３に到達したマイクロ波は遅波板３ｂを伝播し、スロット板３ｃを介して天板４に輻射される。天板４において、マイクロ波は面方向に振動を生じさせて、中心部から周辺部に向けて伝播し、チャンバー１内に電磁界を発生させる。チャンバー１内に発生した電磁界によってアルゴンガスが解離し、基板１１と天板４との間にプラズマ生成領域２２が形成されて、基板１１に所定のプラズマ処理が行われる。

【０００７】

このようなプラズマ処理装置において、基板１１に均一にプラズマを照射する必要がある。ところが、天板４の中心部と周辺部とではプラズマ強度が異なるため、特開２００２－２９９２４０号公報においては、天板４を凹面形状に形成して基板１１と天板４の周辺部との距離を接近させることにより、基板１１の周辺部におけるプラズマ密度の低下を補償し、低圧処理においてもプラズマを維持し、安定なプラズマ処理を可能にすることが記載されている。

【０００８】

また、特開２００３－５９９１９号公報には、誘電体窓にプラズマ励起領域が直接処理容器壁の金属表面と接触しないようにリング状のスリーブを形成して、基板表面で均一なプラズマ密度を得ることが記載されている。

【特許文献１】特開２００２－２９９２４０号公報

【特許文献２】特開２００３－５９９１９号公報

【発明の開示】

【発明が解決しようとする課題】

【０００９】

プラズマ装置では、内部が減圧されるチャンバー１において強度を確保して外気が押す力に対抗するために、天板４として面方向にある程度の厚さが要求される。天板４は誘電体によって構成されており、誘電体にはマイクロ波により共振領域が形成されて強い電界が発生して定在波が形成され、この定在波によりチャンバー１内に電磁界を生じさせ、プラズマ密度が高くなる。定在波を作るには適した誘電体の厚さがある。

【００１０】

図１２は天板の厚さに依存する電界強度分布を示す図である。図１２（ａ）は天板４の面方向の厚さが２２．８ｍｍのときの電界強度分布を示しており、中心の斜線で示す部分が電界強度の強くなっている部分である。図１２（ｂ）は天板４の厚さを２７．８ｍｍにしたときの電界強度分布を示しており、図１２（ａ）に比べて電界強度分布が中心から周辺に広がってきている。図１２（ｃ）は天板４の厚さを３１．６ｍｍにしたときの電界強度分布を示しており、電界強度分布が天板４の中心部分を除いて周辺まで分布しており、最も適した厚さになっている。図１２（ｄ）は天板４の厚さを３２．８ｍｍにしたときの電界強度分布を示しており、電界強度分布が中心部のみ強くなっている。図１２（ｅ）は天板４の厚さを３７．８ｍｍにしたときの電界強度分布を示しており、中心部の電界強度が強くなっている。

【００１１】

図１１に示したプラズマ処理装置において、チャンバー１内の圧力やマイクロ波の電力などのプラズマ条件を変更させるとプラズマ表面近傍の電子密度が変化するため、プラズマが物質に侵入する侵入深さが変化する。圧力を低下させると拡散係数が増大するため、プラズマ表面付近の電子密度が低下して侵入深さが増加する。このようにプラズマ条件を変更すると誘電体の適切な厚さが変わるため、定在波を形成するための共振領域がずれてしまう。このため、常に最適な状態でプラズマを発生するためには、プラズマ条件に応じた種々の厚さを有する誘電体を用意しておく必要があるという問題があった。また、マイクロ波は低圧力でのプラズマへの吸収効率が悪く、低圧（２０ｍＴｏｒｒ）でのプラズマの安定した生成が困難になる。

【００１２】

それゆえに、この発明の目的は、プラズマ条件に応じて天板内に最適な共振領域を形成し、高い圧力から低い圧力にわたってチャンバー内に安定したプラズマの発生が可能なプラズマ処理装置を提供することである。

【課題を解決するための手段】

【００１３】

この発明は、被処理基板を収納し、プラズマを発生するプラズマ発生室と、プラズマ発生室の上部の開口部に配置され、マイクロ波によって駆動されて電磁界を発生するアンテナと、アンテナの下部に設けられて面方向に均一な所定の厚さを有してプラズマ発生室の開口部を封止する天板と、天板の下面側に形成されたテーパ状の凸部または凹部とを備えたことを特徴とする。

【００１４】

この発明では、天板に形成した凸部または凹部のテーパ状部分により、径方向の厚さを連続的に変化させて、プラズマのどの条件においてもどこかで共振させて最適な共振領域を形成できる。したがって、１種類の天板を用意するだけで種々の厚さの天板を用意したのと同様の効果を奏することができる。これにより、プラズマへの吸収効率を飛躍的に向上させることができ、高い圧力から低い圧力にわたって安定したプラズマの発生が可能になる。

【発明を実施するための最良の形態】

【００１５】

好ましくは、天板は凸部または凹部により肉厚の薄い部分と厚い部分とを含み、肉厚の薄い部分の厚みはλ／４±λ／８に選ばれている。

【００１６】

好ましくは、凸部または凹部は、天板の下面にリング状に形成される突条を含む。

【００１７】

好ましくは、天板は円板状であって、突条は天板の中心と同心的に径方向に複数形成される。

【００１８】

好ましくは、突条は天板側の径方向厚さが先端側の径方向厚さよりも厚く形成される。

【００１９】

好ましくは、凸部または凹部は、天板の下面に形成される円錘状の突起を含む。

【００２０】

好ましくは、円錐状の突起は、天板の中心下面に形成される。

【００２１】

好ましくは、円錐状の突起は複数設けられ、複数の円錐状の突起はリング状に配置される。

【００２２】

好ましくは、凸部または凹部は、複数のリング状の凹部と、複数のリング状凹部の間に形成される下向きの第１の突条と、最外周のリング状凹部の外側に形成される下向きの第２の突条とを含む。

【００２３】

好ましくは、第２の凸部の肉厚は、第１の凸部の肉厚に比べて厚く形成される。

【００２４】

好ましくは、天板のアンテナ側の中心部には凹部が形成されており、凹部には天板の誘電率と異なる物質が配置される。

【００２５】

好ましくは、天板の凹部の深さはλ／８以上の深さに形成される。

【００２６】

好ましくは、天板の凹部の深さはλ／４以上の深さに形成される。

【００２７】

好ましくは、天板の被処理基板側の中心部には凸部が形成され、凸部の周辺における天

板の肉厚はλ／４±λ／８である。

【００２８】

好ましくは、被処理基板は円板状であって、凸部または凹部は、被処理基板の半径をＲとしたとき、天板の中心から半径Ｒより外側に少なくとも１つ形成されている。

【００２９】

好ましくは、凸部または凹部は、天板と処理基板との距離をＤとしたとき、天板の中心から半径Ｄより内側に少なくとも１つ形成されている。

【００３０】

好ましくは、アンテナは、面上にスロットが分布して形成されたスロット板を含み、天板にはスロット板上のスロットの位置に対応して凸部または凹部が形成される。

【実施例】

【００３１】

図１はこの発明の一実施形態におけるプラズマ処理装置の断面図であり、図２は図１に示した誘電板を下面から見た図である。

【００３２】

プラズマ処理装置は、前述の図１１と同様にして、基板１１を収容して基板１１に所定の処理を施すためのチャンバー１と、マイクロ波をチャンバー１内に放射するためのアンテナ部３とを備えている。

【００３３】

図示しない高周波電源によって発生されたマイクロ波は、導波管６によりアンテナ部３へ送られる。チャンバー１の上部には、チャンバー１の開口部を封止しかつチャンバー１の隔壁の一部を構成する天板４が配設されており、天板４とチャンバー１の隔壁との間には例えばＯリングなどのシール部材１４が設けられている。アンテナ部３はこの天板４の上方に配置されている。アンテナ部３の上部には内部に冷媒が流れる冷却プレート１０が設けられている。

【００３４】

チャンバー１内には、収納された基板１１を保持するためのサセプタ７が設けられている。サセプタ７は基板１１を加熱するためのヒータ機能を有している。さらに、チャンバー１には、チャンバー１内を排気するために、図１１に示した真空ポンプが接続されている。この真空ポンプによってチャンバー１内が排気されて、所定の圧力範囲の下でプラズマを生成するためのガスとして例えばアルゴンガスがチャンバー１内に導入される。

【００３５】

上述のプラズマ装置では、高周波電源により発生したマイクロ波が導波管６を伝わり、アンテナ部３に到達する。アンテナ部３に到達したマイクロ波は遅波板３ｂを伝播し、スロット板３ｃを介して天板４に共振領域を形成し、定在波を発生させてチャンバー１内に電磁界を発生させる。チャンバー１内に発生した電磁界によってアルゴンガスが解離し、基板１１と天板４との間にプラズマ生成領域２２が形成されて、基板１１に所定のプラズマ処理が行われる。

【００３６】

天板４は強度を確保して外気が押す力に対抗するために面方向に均一な所定の厚さを有する円板状に形成されており、その下面には凸部または凹部が形成されている。より具体的には、凸部または凹部として、天板４の周縁から径方向に所定の間隔を隔てて、周辺部に天板４の中心と同心的にリング状の突条４１が形成されている。この突条４１は外周面が天板４の下面に対して垂直であり、内周面が天板４に対して所定の角度を有するようにテーパ状に形成されて断面が矩形の凸部または凹部を形成している。天板４の周辺部に突条４１を形成するのは、天板４にはアンテナ部３からマイクロ波が供給されており、中心部のプラズマ密度が密になっているのに対して、周辺部では疎になっており、周辺部のプラズマ密度を高めるためである。

【００３７】

図３は天板内をマイクロ波が伝播する状態を説明するための図である。天板４は突条４

１により肉厚の厚い部分と、それ以外の肉厚の薄い部分とが含まれているが、肉厚の薄い部分の厚みをλ／４±λ／８に選ぶことにより、マイクロ波が天板４の肉厚の薄い部分で伝播しにくくなる。

【００３８】

その理由について説明すると、天板内を通過する電磁波の形態には、モードＡとモードＢとが存在する。モードＡは電子密度が所定値以上になると存在し、モードＢは電子密度が比較的小さい場合のみ存在するので、ある程度電子密度が高いときにはモードＢによるマイクロ波伝播は抑制される。

【００３９】

ただし、これは天板厚みに大きく依存し、λ／４以上の厚みでは、厚くなるほどモードＢでの伝播を抑制できる電子密度の下限が高くなってしまう。λ／２以上になると、電子密度に依存せずにモードＢが存在することができるようになるので、モードＢでの伝播は抑制できなくなる。逆に、λ／４以下では、モードＢでの伝播を抑制できる電子密度の下限は変わらない。したがって、天板の強度を考慮するとλ／４が最適となる。ただし、±λ／８の範囲であれば、大方モードＢでの伝播を抑制できることになる。

【００４０】

アンテナ部３に供給されたマイクロ波は、アンテナ部３のスロットから下方向に放射されるが、図３に示すように天板４内で反射され、それが天板４内の反射の繰り返しで面方向に振動して共振領域を形成して定在波となる。（肉厚の薄い部分で伝播しにくいという説明でありながら図３においてマイクロ波が径方向に伝播するように図示されており、辻褄が合わないように思われます。補足説明下さい。）突条部４１に入ったマイクロ波はプラズマ生成領域２２に出難くなるので、突条部分４１にマイクロ波が蓄積されやすくなる。これにより、突条４１を形成したことによる周辺部のプラズマ密度を高めることができる。突条４１部分は天板４の周辺部で共振領域を構成し、マイクロ波が天板４の面方向に直交する径方向に振動する。

【００４１】

突条４１は天板４側の径方向厚さが厚いのに対して、先端側の径方向厚さが薄くなるようにテーパ状に形成されているので、径方向に振動する振幅と突条４１の厚さが一致する部分が必ず存在する。すなわち、突条４１は天板４の周辺部に共振領域を構成し、共振領域がプラズマ密度に応じて自動的に上下するので、プラズマのどの条件においてもどこかで共振するところが存在する。

【００４２】

これにより天板４に最適な共振領域を形成できるので強い電界を発生させて定在波を形成でき、プラズマ密度を高くでき、高い圧力から低い圧力にわたって安定したプラズマの発生が可能になる。

【００４３】

なお、この突条４１は、外周面側および内周面側ともにテーパ状に形成してもよい。また、天板４の厚さに応じて、突条４１を配置する位置あるいは形状を任意に選択すればよい。

【００４４】

前述の特開２００２－２９９２４０号公報には、ドーム状に形成した天板について記載されているが、ドーム形状の場合は共振場所が半径方向に大きく移動し、プラズマの強い場所が移動し、均一性が変化することになる。これに対して、この発明では突条４１により天板４の外周あるいは中心付近にプラズマを集めることによって均一性の調整を行うことができる点において異なっている。

【００４５】

図４はこの発明の他の実施形態における天板に形成した凸部の変形例を示す断面図である。図４（ａ）に示した例は、天板４のほぼ中心の下部に凸部としての円錐状の突起４２を下向きに形成したものである。この例では、突起４２が形成された中心部周辺で共振領域を形成できるので、中心部周辺のプラズマ密度を高くでき、天板４の中心部周辺で電界

強度が小さい場合に有効である。

【００４６】

図４（ｂ）に示した例は天板４の周辺にリング状の突条４３を形成し、外周面および内周面をともにテーパ状に形成したものである。外周面と内周面とをともにテーパ状に形成することで、突条４３の天板側の径方向厚さと先端側の径方向厚さとの差を大きくできるので、突条４３の周辺に形成される共振領域を広げることができ、その周辺のプラズマ密度を高くできる。

【００４７】

図４（ｃ）は図２に示した周辺部の突条４１の他に、中心部に径方向の厚さを突条４１よりも厚くした円錐状の突起４４を形成したものである。この例では、突条４１によって周辺部に共振領域を形成するとともに、突起４４によって中心部に共振領域を形成することで、突条４１の径方向厚さよりも大きな振幅のマイクロ波が入力されても、中央の突起４４で共振領域を構成できるので中心部でプラズマ密度を高くできる。

【００４８】

図５はこの発明のさらに他の実施形態における凹部を形成した天板を示す断面図である。図５（ａ）に示した例は、天板４のほぼ中央部に下向きに開口された円形の凹部４０１を設けたものである。凹部４０１は下部の開口径が大きくなるように内周面がテーパ状に形成されている。この凹部４０１により、その外側には凸部４０２が形成される。この例では、凸部４０２の肉厚の厚い部分で共振領域を形成できるので、この部分でのプラズマ密度を高くでき、天板４の周辺部分での電界密度が小さい場合に有効である。

【００４９】

図５（b）は天板４と同心的にリング状の凹部４０３を設けたものである。凹部４０３の外周面および内周面は下部の開口径が大きくなるようにテーパ状に形成されている。この凹部４０３により、その内側には下向きの凸部４０４が形成され、その外側には突条４０５が形成される。この例では、凸部４０４と突条４０５の肉厚の厚い部分で共振領域を形成できるので、これらの部分でのプラズマ密度を高くできる。

【００５０】

図５（c）は天板４のほぼ中央部に下向きに開口された円形の凹部４０６と、凹部４０６の外側にリング状の凹部４０７とを形成したものである。凹部４０６は下部の開口径が大きくなるように外周面がテーパ状に形成されており、凹部４０７は図５（ｂ）の凹部４０３と同様にして、外周面および内周面は下部の開口径が大きくなるようにテーパ状に形成されている。この例では、凹部４０６の外側に突条４０８が形成され、凹部４０７の外側に突条４０９が形成され、突条４０８と４０９の肉厚の厚い部分で共振領域を形成できるので、これらの部分でのプラズマ密度を高くできる。

【００５１】

図６はこの発明のさらに他の実施形態における天板に形成した凹部の変形例を示す断面図である。この実施形態は、図５（ｃ）に示した例における凹部４０６とリング状の凹部４０７に代えて、凹部４１０とリング状の凹部４１１とを形成したものである。凹部４１０と４１１は下向きに開口されているが、凹部４１０の外周面はテーパ状ではなく円弧状に形成されており、凹部４１１の外周面および内周面も円弧状に形成されている。したがって、この発明におけるテーパ状には円弧状も含まれるものとする。

【００５２】

このように天板４の厚みが円弧状に変化するように形成することで図５（ｃ）と同様にして、凹部４１０およびリング状の凹部４１１の間に突条４１２が形成され、凹部４１１の外側に突条４１３が形成され、これらの肉厚の厚い部分で共振領域を形成できるので、これらの部分でのプラズマ密度を高くできる。

【００５３】

なお、図１～図６に示した実施形態において、天板４に形成するテーパ状部は、図７に示すように基板１１の半径Ｒよりも外側に少なくとも１つ形成するのが望ましい。これにより、基板１１の端部付近でのプラズマ密度が過度に低くならないようにすることができ

る。

【００５４】

さらに、より好ましくは、天板４に形成するテーパ状部は、図７に示した天板４と基板１１との間の距離をＤとすると、天板４の中心から半径Ｄよりも内側に少なくとも１つ形成されているのが望ましい。これにより、天板４の中心付近のプラズマが過度に低くならないようにすることができる。

【００５５】

図８はこの発明のさらに他の実施形態における天板に形成した凹部の変形例を示す断面図である。図８（ａ）に示した例は、天板４の中心部に下向きに突出する凸部４２１を形成し、この凸部４２１の外側付近の天板４の厚みはλ／４±λ／８に選ばれている。さらに、凸部４２１の外側には、下向きに開口されたリング状の凹部４２２を形成するとともに、凹部４２２の外側に、下向きに突出する肉厚の厚い凸部４２３を形成し、凸部４２３の外周部を除いて下面に同心的に複数のリング状の溝４２４を形成する。凸部４２１の外周面と、凸部４２３の内周面はテーパ状に形成されている。

【００５６】

この例では、凹部４２２の外側に肉厚の厚い凸部４２３を形成したことにより強度を高めることができる。また、この凸部４２３部分でのプラズマ密度が高くなり電界密度も高くなってプラズマが放射しやすくなるが、複数のリング状の溝４２４によりその表面からプラズマが放射されるのを抑制でき、溝４２４が形成されていない最外周部からプラズマを放射しやすくなる。

【００５７】

さらに、天板４のアンテナ３側である大気側には凹部４２５が形成されている。この凹部４２５は、その深さがλ／８以上に形成されており、より好ましくはλ／４以上に形成されるのが好ましい。凹部４２５には大気，良導体もしくは天板４とは誘電率の異なる物質（図示せず）が配置される。これはマイクロ波が天板４の中心部の凹部４２５付近で強く反射されるので、この部分でプラズマが強くなりがちであるという問題点を改善するためである。凹部４２５の周辺部の肉厚がλ／４近傍であれば、さらにその効果が助長される。

【００５８】

なお、凹部４２５は天板４のアンテナ３側の中心部に限らず周辺に形成してもよい。

【００５９】

図８（ｂ）に示した例は、天板４の中心部の下部に突出する凸部４２１を形成し、凸部４２１の外側に下部が開口されたリング状の凹部４２２を形成し、凹部４２２の外側に突条４２６を下向きに形成し、さらに突条４２６の外側に下部が開口されたリング状の凹部４２７を形成し、凹部４２７の外側に下向きに突出するリング状の突条４２８を形成したものである。最外周に形成された突条４２８は凸部４２１および突条４２６に比べて肉厚が厚く形成されている。また、凹部４２２および４２７の外周面および内周面はテーパ状に形成されている。

【００６０】

この例では、突条４２６を形成したことにより、天板４の機械的強度を保つことができる。また、突条４２６と４２８とで共振領域が形成されるが、突条４２６に比べて最外周の突条４２８部分の肉厚が厚く形成されていることにより、この部分でのプラズマ密度を突条４２６のプラズマ密度に比べて高くできる。

【００６１】

図８（ｃ）に示した例では、天板４の中央部に下向きに円板状の凸部４２９を形成し、その下面に同心的に複数の溝４３０を形成し、凸部４２９の外側に下向きに開口されたリング状の凹部４３１を形成し、凹部４３１の外側に下向きに突出する突条４３２を形成したものである。突条４３２は凸部４２９に比べて肉厚が厚く形成されている。この例では、天板４の中央部の凸部４２９により肉厚を厚くして機械的強度を高めることができる。凸部４２９は肉厚が厚いためプラズマが伝播しやすくなり、密度が高くなるが溝４３０が

形成されていることによりプラズマが放射され難くなる。そして、凹部４３１の肉厚の薄い部分ではプラズマが伝播しにくくなり、最外周部の突条４３２でのプラズマ密度を高くできる。なお、この例においても、図８（ａ）と同様にして、天板４のアンテナ３側である大気側には凹部４２５が形成されている。

【００６２】

図９はこの発明の他の実施形態として、スロット板のスロットの位置に対応して突条を形成したものである。すなわち、図９（ａ）に示すように円板状のスロット板３ｃには同心円上に三重にリング状に配列されたスロット３１，３２，３３が形成されている。導波管６に入力されるマイクロ波は、スロット板３ｃのスロット３１，３２，３３を介してチャンバー１内に放射されて電磁界が発生される。したがって、天板４のうちスロット３１，３２，３３の位置に対応する部分の電界強度が最も大きくなっている。

【００６３】

そこで、図９（ｂ）に示すように各スロット３１，３２，３３の各位置に対応してリング状の複数の突条４５，４６，４７が形成される。これらの突条４５，４６，４７は、図１に示した突条４１と同様にして外周面が天板４の下面に対して垂直であり、内周面が天板４に対して所定の角度を有するようにテーパ状に形成されているが、外周面側もテーパ状に形成してもよい。天板４のうち各スロット３１，３２，３３の各位置に対応する部分の電界強度が強くなっており、この部分に共振領域を形成することでプラズマを均一にさせることができる。

【００６４】

図１０はこの発明のさらに他の実施形態を示す天板を下から見た図である。前述の図９（ｂ）に示した実施形態は、スロット板３ｃの各スロット３１，３２，３３の位置に対応してリング状の突条４５，４６，４７を形成したのに対して、この実施形態では、各スロット３１，３２，３３の各位置に対応してそれぞれが独立しかつ径の小さな円錐状の突起４８を多数配置したものである。この実施形態においても、各スロット３１，３２，３３で生じた強い電界強度を多数の突起４８によって共振を分散させることができる。

【００６５】

本件発明において、天板４の厚さが２１ｍｍで、天板４の直径が２８０ｍｍで、突条４１の直径が２２０ｍｍで突出高さを２２ｍｍに形成したとき、プラズマ条件としての、例えばプラズマの圧力が１～１００Ｔｏｒｒに変化し、マイクロ波の出力が１００～３０００Ｗ変化したときでも安定したプラズマを発生できる。

【００６６】

図面を参照してこの発明の一実施形態を説明したが、本発明は、図示した実施形態に限定されるものではない。本発明と同一の範囲内において、または均等の範囲内において、図示した実施形態に対して種々の変更を加えることが可能である。

【産業上の利用可能性】

【００６７】

マイクロ波によって駆動されて電磁界を発生するアンテナ部３の下部にチャンバー１の開口部を封止する天板４を設け、天板４の下面側にリング状の突条４１を設けて径方向の厚さをテーパ状に連続的に変化させ、プラズマのどの条件においてもどこかで共振させることにより、高い圧力から低い圧力にわたって安定したプラズマの発生が可能なプラズマ処理装置に利用できる。

【図面の簡単な説明】

【００６８】

【図１】この発明の一実施形態におけるプラズマ処理装置の断面図である。

【図２】図１に示した天板を下面から見た図である。

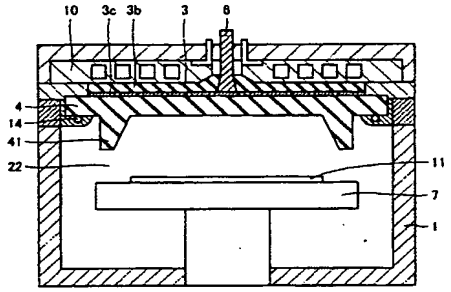
【図３】天板内をマイクロ波が伝播する状態を説明するための図である。

【図４】この発明の他の実施形態における天板に形成した凸部の変形例を示す断面図である。

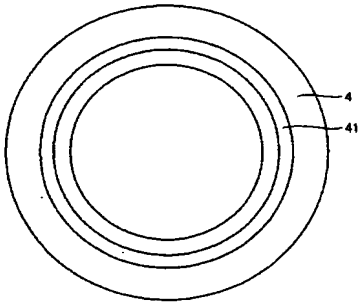
【図５】この発明の他の実施形態における天板に形成した凹部を示す断面図である。

【図６】この発明のさらに他の実施形態における天板に形成した凹部の変形例を示す断面図である。
【図７】凸部または凹部を形成する天板の位置を説明するための図である。
【図８】この発明のさらに他の実施形態における天板に形成した凹部の変形例を示す断面図である。
【図９】この発明の他の実施形態として、スロット板のスロットに対応して天板に突条を形成した例を示す図である。
【図１０】この発明のさらに他の実施形態を示す天板を下から見た図である。
【図１１】従来のプラズマ処理装置の一例を示す断面図である。
【図１２】天板の厚みに依存する電界強度分布を示す図である。
【符号の説明】
【００６９】
１　チャンバー、３　アンテナ部、３ｂ　遅波板、３ｃ　スロット板、４　天板、６　導波管、７　サセプタ、１０　冷却プレート、１１　基板、２２　プラズマ生成領域、３１～３３　スロット、４１，４３，４５～４７，４０５，４０８，４０９，４１２，４１３，４２６，４２８，４３２　突条、４２，４４，４８　突起、４０１，４０３，４０６，４０７，４１０，４１１，４２２，４２５，４２７，４３１　凹部、４０２，４０４，４０８，４１３，４２１，４２３，４２９　凸部、４２４，４３０　溝。

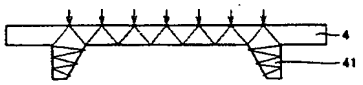
【図１】



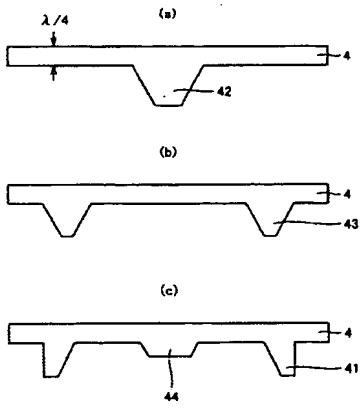
【図２】



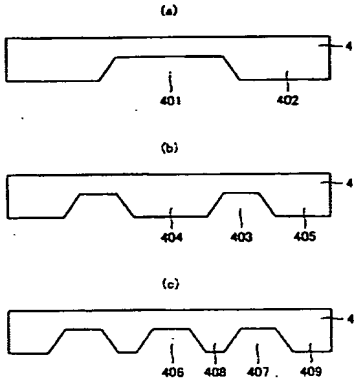
【図３】



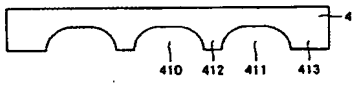
【図４】



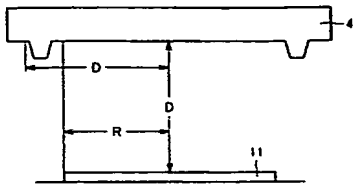
【図５】


(a)
4
401
402
(b)
4
404
403
405
(c)
4
406
408
407
409

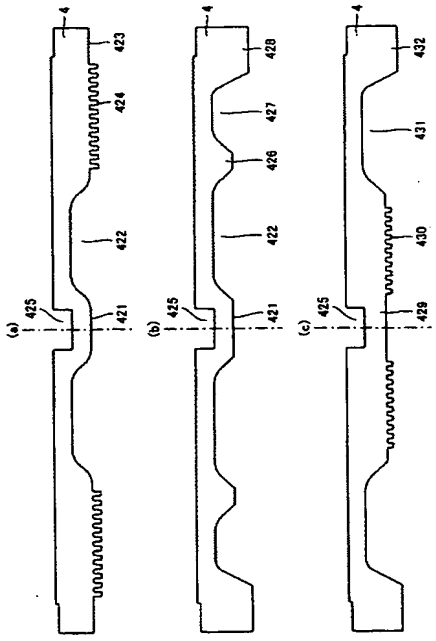
【図６】


4
410
412
411
413

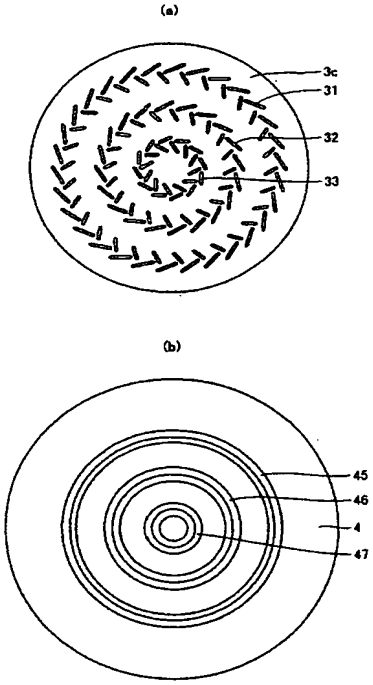
【図７】


4
D
D
R
11

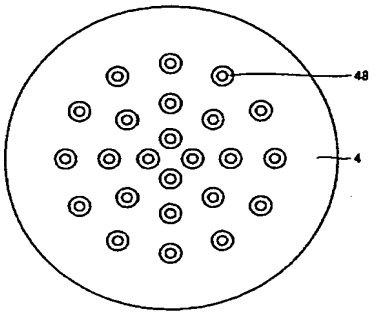
【図８】


4
423
424
422
425
421
(a)
4
428
427
426
422
425
421
(b)
4
432
431
430
425
429
(c)

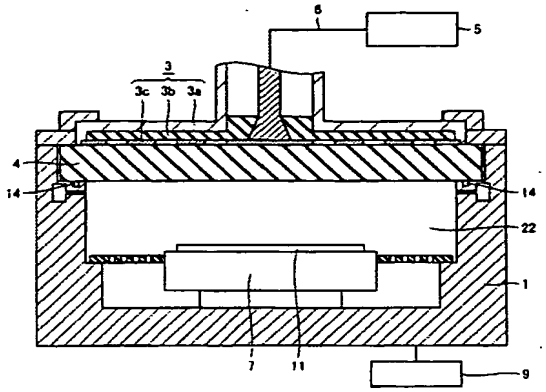
【図９】


(a)
3c
31
32
33
(b)
45
46
4
47

【図１０】



【図１１】



【図１２】